531 Rec'd PCT/PTO 19 OCT 2001

FORM PTO-1390 U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE
(REV. 11-2000)

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
32860-000181

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)
10/030870

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE99/03377	October 21, 1999	April 19, 1999

TITLE OF INVENTION
Robert BOESNECKER

APPLICANT(S) FOR DO/EO/US
FLAT SURFACE LOUDSPEAKER, AND A METHOD FOR ITS OPERATION

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39 (1).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau). WO 00/64217
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is transmitted herewith.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4)
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 20. below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98-1449 and International Search Report (PCT/ISA/210) in German with TEN (10) references.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☒ A substitute specification.
16. ☒ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:
    1) ONE (1) sheet of Formal Drawing
    2.) Article 34 Letter and Amended Specification and Claims

531 Rec'd PCT/PTO 19 OCT 2001

U.S. APPLICATION NO (if known, see 37 CFR 1.5) NEW 10/030870	INTERNATIONAL APPLICATION NO PCT/DE99/03377	ATTORNEY'S DOCKET NUMBER 32860-000181

				CALCULATIONS	PTO USE ONLY
21. ☒ The following fees are submitted: **BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5):**					
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO............			**$1,040.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO			**$890.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO............			**$710.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)			**$690.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4).................			**$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 890.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	16 - 20 =		X **$18.00**	$	
Independent Claims	2 - 3 =		X **$80.00**	$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$270.00**	$	
TOTAL OF ABOVE CALCULATIONS =				$ 890.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$	
SUBTOTAL =				$ 890.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐20 ☐30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 890.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$ 40.00	
TOTAL FEES ENCLOSED =				$ 930.00	
				Amount to be: refunded	$
				charged	$

a. ☐ A check in the amount of $ _____ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account. No. 08-0750 in the amount of $930.00 to cover the above fees. A triplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 08-0750.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

Send all correspondence to:
Harness, Dickey & Pierce, P.L.C – Customer No. 30596
Post Office Box 8910
Reston, Virginia 20195

Date: October 19, 2001

By [signature]
Donald J. Daley, #34,313

DJD/kna

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Express Mail No.: 02-0220
Date of Deposit: October 19, 2001

Applicants: Robert BOESNECKER

Int'l Application No.: PCT/DE99/03377

Application No.: **NEW**

Filed: October 19, 2001

For: FLAT SURFACE LOUDSPEAKER, AND A METHOD FOR ITS OPERATION

Docket No.: 32860-000181

Box PCT
Hon. Commissioner of Patents and Trademarks
Washington, D.C. 20231

EXPRESS MAIL TRANSMITTAL

The following papers are being deposited with the United States Postal Service Express Mail Post Office To Addressee and addressed for receipt by the United States Patent and Trademark Office:

PCT Transmittal Letter (3 copies)
Preliminary Amendment
Marked-Up Version of Specification and Claims
Substitute Specification (9 pages)
Article 34 Letter and Amended Sheets (23 pages)
Recordation Cover Letter and Assignment
Change of Address Letter
Information Disclosure Statement and PTO-1449 (10 references)
Copy of International Application as filed
English language Original Specification (24 pages)
Declaration
One (1) Sheet of Formal Drawing
Change of Address Letter

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Reg #34,313

10/030870

531 Rec'd PCT/PTO 19 OCT 2001

PATENT
32860-000181

IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicants: Robert BOESNECKER

Int'l Application No.: PCT/DE99/03377

Application No.: **NEW**

Filed: October 19, 2001

For: FLAT SURFACE LOUDSPEAKER, AND A METHOD FOR ITS OPERATION

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, DC 20231

October 19, 2001

Sir:

The following preliminary amendments and remarks are respectfully submitted in connection with the above-identified application.

IN THE ABSTRACT

Please replace the Abstract with the attached revised Abstract.

IN THE CLAIMS

Please replace the original claims with the following new claims:

1. (Amended) A method for operation of a flat surface loudspeaker, in which at least one oscillating coil is mounted on a surface, comprising:

emitting sound by at least one coil stimulated to oscillate electrically by a sound source;

measuring the acoustic frequency response of this flat surface loudspeaker;

determining a frequency curve;

determining an inverse frequency curve to the frequency curve;

simulating the inverse frequency curve in a filter device as a transfer function of the filter device; and

compensating for the frequency response of the flat surface loudspeaker by the filter device, which is connected between the sound source and the flat surface loudspeaker in an operating state, based upon the transfer function.

2. (Amended) The method as claimed in claim 1, wherein the transfer function of the filter device is simulated by digital filters.

3. (Amended) The method as claimed in claim 2, wherein the transfer function is formed by FIR (Finite Impulse Response) filters, whose filter coefficients are derived from the inverse frequency curve.

4. (Amended) A flat surface loudspeaker comprising:

at least one oscillating coil, mounted on a surface which, when stimulated by electrical sound signals, causes this surface to oscillate in order to emit sound; and

a filter device for the sound signals, connected upstream of the at least one oscillating coil, wherein a transfer function of the filter device is the inverse of a frequency response of the flat surface loudspeaker.

5. (Amended) The flat surface loudspeaker as claimed in claim 4, wherein the filter device is in the form of a digital filter.

6. (Amended) The flat surface loudspeaker as claimed in claim 5, wherein the filter device is formed by FIR (Finite Impulse Response) filters.

7. (Amended) The flat surface loudspeaker as claimed in claim 5, wherein the filter device includes a sample and hold element as the input element, connected via an analogue-to-digital converter to the digital filter, whose output is connected to a digital-to-analogue converter.

8. (Amended) The flat surface loudspeaker as claimed in claim 5, wherein the filter device is equipped with a digital signal processor.

Please add the following new claims:

-- 9. The flat surface loudspeaker as claimed in claim 6, wherein the filter device includes a sample and hold element as the input element, connected via an analogue-to-digital converter to the digital filter, whose output is connected to a digital-to-analogue converter.

10. The flat surface loudspeaker as claimed in claim 6, wherein the filter device is equipped with a digital signal processor.

11. The flat surface loudspeaker as claimed in claim 7, wherein the filter device is equipped with a digital signal processor.

12. The flat surface loudspeaker as claimed in claim 9, wherein the filter device is equipped with a digital signal processor.

13. The method of claim 1, wherein the at least one of oscillating coil is mounted on a surface in the form of a plate.

14. The method of claim 1, wherein the at least one oscillating coil has predetermined material characteristics.

15. The flat surface loudspeaker as claimed in claim 4, wherein the at least one oscillating coil is mounted on a surface in the form of a plate.

16. The flat surface loudspeaker as claimed in claim 4, wherein the at least one oscillating coil has predetermined material characteristics. --

REMARKS

Claims 1-16 are now present in this application, with new claims 9-16 being added by the present Preliminary Amendment. It should be noted that the amendments to original claims 1-16 of the present application are non-narrowing amendments, made solely to place the claims in proper form for U.S. practice and not to overcome any prior art or for any other statutory considerations. For example, amendments have been made to broaden the claims; remove reference numerals in the claims; remove the European phrase "characterized in that"; remove multiple dependencies in the claims; and to place claims in a more recognizable U.S. form, including the use of the transitional phrase "comprising" as well as the phrase "wherein". Other such non-narrowing amendments include changing the phrase "or" to --at least one of--, and reorganizing method (separate clauses beginning with "-ing" verbs) and apparatus-type claims (elements set forth in separate paragraphs) in a more recognizable U.S. form. Again, all amendments are non-narrowing and have been made solely to place the claims in proper form for U.S. practice and not to overcome any prior art or for any other statutory considerations.

SUBSTITUTE SPECIFICATION

In accordance with 37 C.F.R. §1.125, a substitute specification has been included in lieu of substitute paragraphs in connection with the present Preliminary Amendment. The

substitute specification is submitted in clean form, attached hereto, and is accompanied by a marked-up version showing the changes made to the original specification. The changes have been made in an effort to place the specification in better form for U.S. practice. No new matter has been added by these changes to the specification. Further, the substitute specification includes paragraph numbers to facilitate amendment practice as requested by the U.S. Patent and Trademark Office.

CONCLUSION

Accordingly, in view of the above amendments and remarks, an early indication of the allowability of each of claims 1-16 in connection with the present application is earnestly solicited.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Donald J. Daley at the telephone number of the undersigned below.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 08-0750 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17; particularly, extension of time fees.

Respectfully submitted,

HARNESS, DICKEY & PIERCE, P.L.C

By: ______________________

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10/030870
531 Rec'd PCT/PTO 19 OCT 2001

New U.S. Application
Docket No.: 32860-000181

ABSTRACT OF THE DISCLOSURE

In a method for operation of a flat surface loudspeaker, at least one oscillating coil is mounted on a surface in the form of a plate and having predetermined material characteristics. The surface is caused to oscillate by the at least one oscillating coil, which is stimulated electrically by a sound source. The acoustic frequency response of this flat surface loudspeaker is measured, and the inverse frequency curve to this frequency curve is determined. This inverse frequency curve is simulated in a filter device as its transfer function.

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10/030870
531 Rec'd PCT/PTC 19 OCT 2001

New U.S. Application
Docket No. 32860-000181

SUBSTITUTE SPECIFICATION

FLAT SURFACE LOUDSPEAKER, AND A METHOD FOR ITS OPERATION

[0001] This application is the national phase under 35 U.S.C. § 371 of PCT International Application No. PCT/DE99/03377 which has an International filing date of October 21, 1999, which designated the United States of America, the entire contents of which are hereby incorporated by reference.

Field of the Invention

[0002] The invention generally relates to a flat surface loudspeaker, and to a method for its operation.

Background of the Invention

[0003] Flat surface loudspeakers have been generally known for a long time, for example from German Patent 484 872. An oscillating coil is used in a flat surface loudspeaker, operating on the electrodynamic principle and being placed directly on a surface – intrinsically initially of any desired size and thickness and composed of a chosen material -, and being mechanically fixed there. When the oscillating coil is stimulated electrically by a sound transmitter, then its oscillations are transmitted to the surface. The surface acts as a membrane, so that it is itself used as a sound-emitting surface. There will be a large number of potential applications per se for an electroacoustic transducer of this generic type. Apart from a few exceptions, it has nevertheless not been used to any major extent so far, due to its electroacoustic characteristics, in particular its transfer function.

[0004] The operation of the sound-emitting surface is primarily governed by its mechanical characteristics. This surface can transmit sounds or tones only by oscillating mechanically. Quite apart from the means by which it is clamped in, that is to say the mechanical mounting and the point at which the oscillating coil is fixed on it, a surface in the form of a plate in which, preferably, bending oscillations are stimulated is intrinsically a relatively complex structure in terms of its oscillation behavior. Whereas with commercially available loudspeakers, based on the electrodynamic principle it is still largely possible, even if actually only by making compromises, to optimize the acoustic characteristics of the sound-emitting membrane, this is not directly possible with flat surface loudspeakers.

[0005] This problem can be illustrated by an example: if the glass surface of a shop window on which an oscillating coil is mounted is used as a flat surface loudspeaker, then the material, shape and dimensions of the sound-emitting surface, and the way in which it is clamped in as well, are essentially fixed. In this example, the frequency response of the flat surface loudspeaker is thus essentially predetermined. Typically, the natural resonances of the

surface used for sound emission and with this material and the dimensions of the shop window have a frequency response which – in simple terms – can be described by enhanced response in the low frequency area and, furthermore, by a tendency to produce a tinkling noise, which is due to the influence of higher-order natural resonances that are still in the audible range. Corresponding characteristic nonlinearities also occur with other materials, such as wood or synthetic materials.

[0006] A flat surface loudspeaker having a built-in sound wall is known from GB 2 265 519 A, which has nonlinearities in transmission owing to the internal air pressure and the magnetic field in the transducer. The nonlinearities are taken into account by way of digital electronic compensation; the loudspeaker contains power amplification. This allows the loudspeaker to be designed to be much thinner than would otherwise be possible. The drive forces are exerted on a major proportion of a membrane in order to avoid modal distortion which occurs in the sound-emitting surface at low and medium frequencies. The loudspeaker is suitable for wall mounting, with minimal projection into the room.

[0007] GB 289 185 A discloses an acoustic reproduction appliance, for amplification of the power on an audiosignal, which has been modified by a nonrecursive digital filter, and which emits the sound via a loudspeaker. The reproduction appliance has a sound funnel in the form of a horn on the loudspeaker, as well as a device for signal processing of the audio signal, including a nonrecursive digital filter. An acoustic resistance can be mounted on the opening of the loudspeaker horn. The filter has an inverse characteristic to the transmission characteristic of the loudspeaker horn, including the acoustic resistance. Furthermore, the reproduction appliance may have a linear phase equalizer for modulation of the amplitude characteristic of the audio signal. The digital filter in the signal processing device may be in the form of a digital FIR (Finite Impulse Response) filter.

[0008] EP 0 168 078 A1 discloses an arrangement for converting an electrical signal to an acoustic signal or vice versa, which has an electroacoustic transducer and a device for reducing the distortion in the output signal from the arrangement. The device is in the form of a nonlinear network which has at least two parallel circuit branches, at least one of which compensates for the second or higher order nonlinear distortion components.

[0009] An appliance to compensate for reproduction errors in an electroacoustic transducer, such as a loudspeaker or a microphone, by a computer circuit is known from US 4,675,835. The electrical input signals are converted in a digital computer circuit to output signals which have been modified by inherent characteristics of the transducer, and are stored in a memory by a program. The program is stored in the same way. When analogue computer circuits are used, the complex inherent reproduction of the transducer, in terms of the amplitude/frequency transmission and the phase/ frequency transmission, is approximated mathematically in a closed inverse form. The resulting function is simulated by way of integrated, addition, inversion and adjustment elements.

[0010] A method and a system for transmission of audio frequencies in a sound reproduction system are disclosed in EP 0 567 061 A1, which sound reproduction system has at least one loudspeaker mounted in a housing, and in which the frequency transmission of the loudspeaker is equalized by a filter. Before feeding in a signal in a broadband one-way loudspeaker, which reproduces frequencies essentially over the entire audible range, with the loudspeaker emitting audio signals. The frequency transmission of the loudspeaker when mounted in its housing is equalized by a filter, which is likewise a broadband filter covering the entire audible range. The filter provides an approximated inverse transmission in the desired pass band of the loudspeaker system, which includes the loudspeaker mounted in its housing, with the inverse transmission being formed on the basis of the measured frequency transmission of the loudspeaker system. If desired, the measured frequency transmission can be averaged in the frequency domain, and the inverse transmission is then formed from the averaged frequency transmission.

[0011] As is known, for example, from US-A-3 728 497 as well as US-A-3 636 281 or US-A-3 449 531, efforts have been made to overcome the known disadvantages of a flat surface loudspeaker by physical measures. Certain improvements have been possible in this way, but a fundamental solution which would give flat surface loudspeakers a wide range of applications has not yet been obtained from the experiments carried out so far.

SUMMARY OF THE INVENTION

[0012] The invention is thus based on a first partial object of specifying a device, using a method of the type mentioned initially, using which the nonlinearities in the frequency response of flat surface loudspeakers can at least be coped with to such an extent that their sound spectrum is sufficiently natural for the respective application.

[0013] A second partial object is to use such a method to provide a flat surface loudspeaker of the type mentioned initially, whose electroacoustic characteristics are – depending on the application – optimized such that predetermined requirements in an individual application relating to the quality of sound produced in this way are thus satisfied.

[0014] In a method of this generic type for operating a flat surface loudspeaker, the first partial object is achieved, for example, by the features described in patent claim 1.

[0015] In a flat surface loudspeaker of the type mentioned initially, the second partial object is achieved, for example, by the features described in patent claim 4.

[0016] In the field of electroacoustics, it has long been known in the development of optimized electroacoustic transducers that the effects of the influencing variables which govern the transmission quality of an electroacoustic transducer often counter one another in a contrary manner. A physical/mechanical solution in which all these influencing variables are optimized in the same way is thus impossible, and every electroacoustic transducer is

invariably a compromise solution, due to systematic factors. One relevant example of this is the known loudspeaker box, with a number of individual, specifically designed loudspeakers.

[0017] Solutions to the two partial objects according to the invention are based on the joint idea that such compromises, which are characterized by physical measures, have far less probability of leading to a satisfactory result in a flat surface loudspeaker. A flat surface loudspeaker is actually not composed of individual, specifically designed loud speaker units, like a loudspeaker box. The development of flat surface loudspeakers so far has shown that solution approaches which attempted to improve flat surface loudspeakers by physical measures did not lead to a satisfactory result.

[0018] The invention is a departure from the conventional ideas of electro-acousticians and adopts a different approach. The electroacoustic characteristics of flat surface loudspeakers are governed by the total effect of the characteristics of the oscillating coil or coils used, and by the mechanical characteristics of the sound-emitting surface that is used. The electroacoustic transfer function for each arrangement of a flat surface loudspeaker defined in this way is thus defined in the form of its frequency response – apart from tolerances. If the corresponding frequency curve is determined by measurement, then the frequency response of the flat surface loudspeaker can be compensated for, and hence linearized, by a filter device which is arranged in the operating arrangement of the flat surface loudspeaker between the sound source and the amplifier located upstream of the oscillating coil or oscillating coils, provided that the transfer function of the filter device is essentially the inverse of the corresponding function for the combination of an oscillating coil or coils and the sound-emitting surface.

[0019] According to developments of the invention, the transfer function of the filter device is simulated by digital filters, in particular by means of FIR (Finite Impulse Response) filters, whose filter coefficients are derived from the inverse frequency curve of the flat surface loudspeaker.

[0020] The filter device preferably has a sample and hold element as the input element, which is connected via an analogue/digital converter to the digital filter, whose output is connected to a digital/analogue converter.

[0021] According to another development of the invention, the filter device is equipped with a digital signal processor.

[0022] Nowadays, digital signal processors are widely used and, owing to the progress in the development of integrated circuits, are also already available for relatively computation-intensive "real time" applications. Digital signal processors are freely programmable, even if this is only to a limited extent due to the available volume for the program memory. It is thus possible to match the operation of the digital signal processor to different sound-emitting surface materials, such as wooden materials, glass, plastics, and, inter alia, polyurethane

foam. Furthermore, it is also possible to provide sound-emitting surfaces with different shapes.

[0023] It is thus clear that the invention has, in particular, overcome the greatest obstruction to the widespread use of flat surface loudspeakers in the past. The shape and material selection for the sound-emitting surface are largely unconstrained, without any need to accept any reduction in the sound emission quality. Although very high quality, which is thus still relatively expensive due to complexity reasons, is not required for every application, it is nevertheless feasible to implement embodiments which even completely satisfy hifi (high fidelity) requirements. Volume and weight savings with flat surface loudspeakers compared to commercially available loudspeaker boxes are a major advantage, and not only in these applications.

[0024] Further advantages and refinements of the solution according to the invention can be found in the following description of exemplary embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Exemplary embodiments of the invention will be described in more detail in the following text with reference to the drawing, in which:

Figure 1 shows a flat surface loudspeaker in conjunction with a measurement arrangement for measuring its frequency response,

Figure 2 shows a first embodiment of the circuit arrangement for operating the flat surface loudspeaker, and

Figure 3 shows a further embodiment of the circuit arrangement as shown in Figure 2.

DETAILED DESCRIPTION OF THE PREFERRED EMODIMENTS

[0026] Figure 1 shows, schematically, a flat surface loudspeaker 1 which has a sound-emitting surface 2 in the form of a plate and on which, by way of example, two oscillating coils 3 and 4 are arranged. The oscillating coils 3 and 4 are mechanically fixed on the sound-emitting surface 2 such that, when they are electrically stimulated, the mechanical oscillations which they carry out in this case are transmitted to the sound-emitting surface 2 in order that it is itself caused to oscillate, and hence to emit sound. In a functional operating circuit, the oscillating coils 3, 4 are connected in parallel to the outputs of an amplifier 5 whose input, during normal operation, is coupled to a sound source, which is not shown in Figure 1.

[0027] For a person skilled in the art of technical acoustics, it is immediately evident that, inter alia, the characteristics of the sound-emitting surface 2, its shape, the size of its surface area, it thickness and, above all, also its mechanical characteristics together with the configuration of the oscillating coil or coils 3 and 4 as well as their local arrangement on the

sound-emitting surface 2 govern the acoustic characteristics of the flat surface loudspeaker 1. Since, for example, completely different materials can be used for the sound-emitting surface 2, this itself results in a difficulty in material selection. This is because this depends on whether the flat surface loudspeaker 1 has a high level of attenuation, on the one hand in particular in the higher frequency range, as in the case of wooden materials, or on the other hand in the low-frequency range as, for example, in the case of glass and plastics so that, in the latter case, high frequency components are reproduced excessively, thus resulting in a tendency to tinkling.

[0028] These problems have resulted in flat surface loudspeakers not so far being used in large numbers in intrinsically feasible applications, even though the principles relating to this have been known for a very long time, since other electroacoustic transducers are known whose frequency response can be corrected more easily.

[0029] In order to solve this problem, Figure 1 now also shows a measurement arrangement by way of which the transmission characteristics of a flat surface loudspeaker 1 are analyzed acoustically. In order to determine the frequency response of the measurement object, that is to say of a specific type of flat surface loudspeaker 1, a frequency analyzer 6 is provided which emits a defined electrical measurement signal to the amplifier 5 at a predetermined level and at a tunable frequency, and causes the flat surface loudspeaker 1 to emit sound via the oscillating coils 3, 4. A measurement microphone 7, which is connected to the input of the frequency analyzer 6, is arranged at a defined distance from the flat surface loudspeaker 1, preferably along its center axis.

[0030] The frequency response of the measurement object is determined using this measurement arrangement, which is preferably set up in an anechoic room, in order to simulate sound propagation in free space as exactly as possible in measurement conditions. As indicated above, this frequency response of a flat surface loudspeaker 1 is governed by object-typical nonlinearities, for which reason it must be measured individually, at least for each object type. This results in an essential measure for the electroacoustic transmission characteristics of a flat surface loudspeaker 1. The inverse function of the frequency curve obtained in this way is formed in order to compensate for the nonlinearities of the frequency response.

[0031] Figure 2 uses an operating circuit for the flat surface loudspeaker 1 to illustrate, schematically, how the described measurement result is used in order to correct for the distortion in the transmission characteristics of a specific electroacoustic transducer. By way of example, the sound source is illustrated in Figure 2 in the form of a magnetic tape recorder 7, whose output is connected to the amplifier 5 for the flat surface loudspeaker 1, via a filter device 8. As is indicated schematically in Figure 2, a transfer function is implemented in the filter device 8 which is essentially the inverse of the characteristic frequency curve measured for this type of flat surface loudspeaker 1. The profile of the transfer function of the filter

device 8 must be approximated more closely to the inverse frequency curve of the flat surface loudspeaker 1 the more stringent the requirements to which the resultant transmission quality of the flat surface loudspeaker 1 is subject in the respective application.

[0032] In the filter device 8, the electrical sound signals supplied from the magnetic tape recorder 8 are subjected to preemphasis in such a way that this just counteracts the frequency response of the flat surface loudspeaker 1. This sound signal, with preemphasis, is supplied via the amplifier 5 to the oscillating coils 3, 4 of the flat surface loudspeaker 1. The transfer function of the conversion to acoustic signals in the flat surface loudspeaker 1 counteracts this preemphasis once again. The resultant frequency response of the flat surface loudspeaker 1 is better linearized the more accurately the transfer function of the filter device 8 approximates to the inverse frequency curve of the flat surface loudspeaker 1.

[0033] As is known, electrical filters can also be formed from discrete elements, but complex transfer functions for a bandpass filter in the audible range, such as those which are used in this field of application in conjunction with flat surface loudspeakers 1, can be provided using discrete components only with great complexity, and then only to a first approximation. Implementations of the filter device 8 using discrete components are therefore suitable in conjunction with a flat surface loudspeaker 1 only when its transmission quality is subject only to restricted requirements in a particular application.

[0034] Figure 3 thus shows a further embodiment for the operating circuit of a flat surface loudspeaker 1, by way of which even hifi (high fidelity) requirements can be satisfied. The embodiment shown in Figure 3 differs from the embodiment shown in Figure 2 in the further refinement of the filter device 8. Figure 3 shows the filter device 8 as a digital filter. Its input circuit, which is connected to the magnetic tape recorder 7 (which is indicated once again as an example of a sound source) is in the form of a sample and hold element 9 – frequently also referred to as a sample and hold circuit. The electrical sound signal supplied as an analogue signal from the magnetic tape recorder 8 is thus sampled using a predetermined sampling theorem, and the respectively sampled instantaneous value is buffer-stored and is supplied to an analogue/digital converter 10 which is connected to it and which converts the successive instantaneous values to digital signals expressed in binary form. The signals are supplied in this form to a digital signal processor 11. On the output side, the digital signal processor 11 is connected to a digital/analogue converter 12, by means of which its binary output signal is converted back to an analogue electrical signal, which is supplied via the amplifier 5 to the flat surface loudspeaker 1.

[0035] This refinement of the filter device 8 advantageously makes use of the progress in the development of digital signal processing. Nowadays, the semiconductor industry offers the user powerful signal processors, which are already in widespread use, even for real-time applications. Application options for digital signal processors as well as refinements by means of appropriate programs can therefore be assumed to be known in this case. The circuit

design of the digital signal processor is therefore not shown in detail in the schematic illustration in Figure 3. Normally, in addition to a microcontroller, the actual control unit, has a signal processor a program memory, a data memory and an input/output memory, which are connected to one another via a bus system with parallel address, control and data lines. The capability to store a specific program relating to the respective application in the program memory makes the digital signal processor suitable for an electronic circuit which can be used universally and, in the present field of application, is used to simulate the transfer function of the filter device 8.

[0036] It is advantageous in this case for the filter or filters to be in the form of FIR (Finite Impulse Response) filters, by which even complex transfer functions for real-time requirements can be provided in a known manner. If the transmission quality of the flat surface loudspeaker is subject to very stringent requirements, such as those for hifi quality, in a specific application. Then, owing to the signal processing required in real-time conditions, it may be necessary to carry out this signal processing by parallel operation of a number of signal processors, without in the process needing to depart from the fundamental solution approach.

[0037] The embodiments described above open up a wide range of applications for flat surface loudspeakers. The capability to program the digital signal processor 11 freely allows the complexity for the measurement of the frequency response of the respective type of flat surface loudspeaker 1 and the conversion of the measured frequency curve to an inverse transfer function (which is a greater or lesser approximation of this) of the filter device 8 to be optimized for the respective application. Both physically small and large format flat surface loudspeakers can be produced. Since the choice of materials for a flat surface loudspeaker designed according to the invention is no longer to a major extent subject to the conventional restriction, even materials with a very low relative density, for example, can also be chosen for the sound-emitting surface. Particularly in mobile applications, in which transport capabilities invariably play a substantial role, it is a major advantage to move a light flat surface loudspeaker composed of polyurethane foam instead of a heavy, voluminous conventional loud speaker box. Flat surface loudspeakers according to the invention can thus be used not only for commercial purposes, such as public sound-emission facilities and advertising hoardings, but also as high-quality loudspeaker device in the personal field, which are at the same time very flat and, for example, are integrated in furniture.

[0038] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

MARKED-UP VERSION OF SPEC 32860-181P ①

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~~Description~~

PCT 98

Flat surface loudspeaker, and a method for its operation

FIELD OF THE INVENTION

The invention generally relates to a flat surface loudspeaker~~, as claimed in the precharacterizing clause of patent claim 4,~~ and to a method for its operation~~, as claimed in the precharacterizing clause of patent claim 1~~.

BACKGROUND OF THE INVENTION

Flat surface loudspeakers ~~of said generic type~~ have been generally known ~~per se~~ for a long time, for example from German Patent 484 872. An oscillating coil is used in a flat surface loudspeaker, operating on the electrodynamic principle and being placed directly on a surface - intrinsically initially of any desired size and thickness and composed of a chosen material -, and being mechanically fixed there. When the oscillating coil is stimulated electrically by a sound transmitter, then its oscillations are transmitted to the surface~~,~~. ~~which~~ The surface acts as a membrane, so that it is itself used as a sound-emitting surface. There will be a large number of potential applications per se for an electroacoustic transducer of this generic type. Apart from a few exceptions, it has nevertheless not been used to any major extent so far, o~~wing~~ due to its electroacoustic characteristics, in particular its transfer function.

The operation of the sound-emitting surface is primarily governed by its mechanical characteristics. This surface can transmit sounds or tones only by oscillating mechanically. Quite apart from the means by which it is clamped in, that is to say the mechanical mounting and the point at which the oscillating coil is fixed on it, a surface in the form of a plate in which,

preferably, bending oscillations are stimulated is intrinsically a relatively complex structure in terms of its oscillation behavior. Whereas with commercially available loudspeakers, based on the electrodynamic principle it is still largely possible, even if actually only by making compromises, to optimize the acoustic characteristics

of the sound-emitting membrane, this is not directly possible with flat surface loudspeakers. This problem can be illustrated by an example: if the glass surface of a shop window on which an oscillating coil is mounted is used as a flat surface loudspeaker, then the material, shape and dimensions of the sound-emitting surface, and the way in which it is clamped in as well, are essentially fixed. In this example, the frequency response of the flat surface loudspeaker is thus essentially predetermined. Typically, the natural resonances of the surface used for sound emission and with this material and the dimensions of the shop window have a frequency response which - in simple terms - can be described by enhanced response in the low frequency area and, furthermore, by a tendency to produce a tinkling noise, which is due to the influence of higher-order natural resonances that are still in the audible range. Corresponding characteristic nonlinearities also occur with other materials, such as wood or synthetic materials.

A flat surface loudspeaker having a built-in sound wall is known from GB 2 265 519 A, which has nonlinearities in transmission owing to the internal air pressure and the magnetic field in the transducer. The nonlinearities are taken into account by ~~means~~ way of digital electronic compensation; the loudspeaker contains power amplification. This allows the loudspeaker to be designed to be much thinner than would otherwise be possible. The drive forces are exerted on a major proportion of a membrane in order to avoid modal distortion which occurs in the sound-emitting surface at low and medium frequencies. The loudspeaker is suitable for wall mounting, with minimal projection into the room.

4 GB 289 185 A discloses an acoustic reproduction appliance, for amplification of the power on an audiosignal, which has been modified by ~~means of~~ a nonrecursive digital filter, and which emits the sound via a loudspeaker. The reproduction appliance has a sound funnel in the form of a horn on the loudspeaker, as well as ~~means~~ a device for signal processing of the audio signal, ~~comprising~~ including a nonrecursive digital filter. An acoustic resistance can be mounted on the opening of the loudspeaker horn. The filter has an inverse characteristic to the transmission characteristic of the loudspeaker horn, including the acoustic resistance. Furthermore, the reproduction appliance may have a linear phase equalizer for modulation of the amplitude characteristic of the audio signal. The digital filter in the signal processing ~~means~~ device may be in the form of a digital FIR (Finite Impulse Response) filter.

EP 0 168 078 A1 discloses an arrangement for converting an electrical signal to an acoustic signal or vice versa, which has an electroacoustic transducer and ~~means~~ a device for reducing the distortion in the output signal from the arrangement. The ~~means are~~ device is in the form of a nonlinear network which has at least two parallel circuit branches, at least one of which compensates for the second or higher order nonlinear distortion components.

An appliance to compensate for reproduction errors in an electroacoustic transducer, such as a loudspeaker or a microphone, by ~~means of~~ a computer circuit is known from US 4,675,835. The electrical input signals are converted in a digital computer circuit to output signals which have been modified by inherent characteristics

of the transducer, and are stored in a memory by ~~means of~~ a program. The program is stored in the same way. When analogue computer circuits are used, the complex inherent reproduction of the transducer, in terms of the amplitude/frequency transmission and the phase/frequency transmission, is approximated mathematically in a closed inverse form. ~~and~~ The resulting function is simulated by way ~~means~~ of integrated, addition, inversion and adjustment elements.

A method and a system for transmission of audio frequencies in a sound reproduction system are disclosed in EP 0 567 061 A1, which sound reproduction system has at least one loudspeaker mounted in a housing, and in which the frequency transmission of the loudspeaker is equalized by ~~means of~~ a filter. Before feeding in a signal in a broadband one-way loudspeaker, which reproduces frequencies essentially over the entire audible range, with the ~~said~~ loudspeaker emitting audio signals. The frequency transmission of the loudspeaker when mounted in its housing is equalized by ~~means of~~ a filter, which is likewise a broadband filter covering the entire audible range. The filter provides an approximated inverse transmission in the desired pass band of the loudspeaker system, which includes ~~comprises~~ the ~~said~~ loudspeaker mounted in its housing, with the inverse transmission being formed on the basis of the measured frequency transmission of the loudspeaker system. If desired, the measured frequency transmission can be averaged in the frequency domain, and the inverse transmission is then formed from the averaged frequency transmission.

As is known, for example, from US-A-3 728 497 as well as US-A-3 636 281 or US-A-3 449 531, efforts have been made to overcome the known disadvantages of a flat surface loudspeaker by ~~means of~~ physical measures. Certain improvements have been possible in this way, but a fundamental solution which would give flat surface loudspeakers a wide range of applications has not yet been obtained from the experiments carried out so far.

SUMMARY OF THE INVENTION

The invention is thus based on a first partial object of specifying a device ~~means~~, using a method of the type mentioned initially, using which the nonlinearities in the frequency response of flat surface loudspeakers can at least be coped with to such an extent that their sound spectrum is sufficiently natural for the respective application.

A second partial object is to use such a method to provide a flat surface loudspeaker of the type

mentioned initially, whose electroacoustic characteristics are - depending on the application - optimized such that predetermined requirements in an individual application relating to the quality of sound produced in this way are thus satisfied.

In a method of this generic type for operating a flat surface loudspeaker, the first partial object is achieved, for example, by the features described in ~~the characterizing part of~~ patent claim 1.

In a flat surface loudspeaker of the type mentioned initially, the second partial object is achieved, for example, by the features described in ~~the characterizing part of~~ patent claim 4.

In the field of electroacoustics, it has long been known in the development of optimized electroacoustic transducers that the effects of the influencing variables which govern the transmission quality of an electroacoustic transducer often counter one another in a contrary manner. A physical/mechanical solution in which all these influencing variables are optimized in the same way is thus impossible, and every electroacoustic transducer is invariably a compromise solution, due to systematic factors. One relevant example of this is the known loudspeaker box, with a number of individual, specifically designed loudspeakers. The solutions to the two partial objects according to the invention are based on the joint idea that such compromises, which are characterized by physical measures, have far less probability of leading to a satisfactory result in a flat surface loudspeaker. A flat surface loudspeaker is actually not composed of individual, specifically designed loud speaker units,

like a loudspeaker box. The development of flat surface loudspeakers so far has shown that solution approaches which attempted to improve flat surface loudspeakers by physical measures did not lead to a satisfactory result.

The invention is a departure from the conventional ideas of electro-acousticians and adopts a different approach. The electroacoustic characteristics of flat surface loudspeakers are governed by the total effect of the characteristics of the oscillating coil or coils used, and by the mechanical characteristics of the sound-emitting surface that is used. The electroacoustic transfer function for each arrangement of a flat surface loudspeaker defined in this way is thus defined in the form of its frequency response - apart from tolerances. If the corresponding frequency curve is determined by measurement, then the frequency response of the flat surface loudspeaker can be compensated for, and hence linearized, by ~~means of~~ a filter device which is arranged in the operating arrangement of the flat surface loudspeaker between the sound source and the amplifier located upstream of the oscillating coil or oscillating coils, provided that the transfer function of the filter device is essentially the inverse of the corresponding function for the combination of an oscillating coil or coils and the sound-emitting surface.

According to developments of the invention, the transfer function of the filter device is simulated by ~~means of~~ digital filters, in particular by means of FIR (Finite Impulse Response) filters, whose filter coefficients are derived from the inverse frequency curve of the flat surface loudspeaker.

The filter device preferably has a sample and hold element as the input element, which is connected via an analogue/digital converter to the digital filter, whose output is connected to a digital/analogue converter.

According to another development of the invention, the filter device is equipped with a digital signal processor.

Nowadays, digital signal processors are widely used and, owing to the progress in the development of integrated circuits, are also already available for relatively

computation-intensive "real time" applications. Digital signal processors are freely programmable, even if this is only to a limited extent due to the available volume for the program memory. It is thus possible to match the operation of the digital signal processor to different sound-emitting surface materials, such as wooden materials, glass, plastics, and, inter alia, polyurethane foam. Furthermore, it is also possible to provide sound-emitting surfaces with different shapes.

It is thus clear that the invention has, in particular, overcome the greatest obstruction to the widespread use of flat surface loudspeakers in the past. The shape and material selection for the sound-emitting surface are largely unconstrained, without any need to accept any reduction in the sound emission quality. Although very high quality, which is thus still relatively expensive due to complexity reasons, is not required for every application, it is nevertheless feasible to implement embodiments which even completely satisfy hifi (high fidelity) requirements. Volume and weight savings with flat surface loudspeakers compared to commercially available loudspeaker boxes are a major advantage, and not only in these applications.

Further advantages and refinements of the solution according to the invention can be found in the following description of exemplary embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the invention will be described in more detail in the following text with reference to the drawing, in which:

Figure 1 shows a flat surface loudspeaker in conjunction with a measurement arrangement for measuring its frequency response,

Figure 2 shows a first embodiment of the circuit arrangement for operating the flat surface loudspeaker, and

Figure 3 shows a further embodiment of the circuit arrangement as shown in Figure 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

¶ Figure 1 shows, schematically, a flat surface loudspeaker 1 which has a sound-emitting surface 2 in the form of a plate and on which, by way of example, two oscillating coils 3 and 4 are arranged. The oscillating coils 3 and 4 are mechanically fixed on the sound-emitting surface 2 such that, when they are electrically stimulated, the mechanical oscillations which they carry out in this case are transmitted to the sound-emitting surface 2 in order that it is itself caused to oscillate, and hence to emit sound. In a functional operating circuit, the oscillating coils 3, 4 are connected in parallel to the outputs of an amplifier 5 whose input, during normal operation, is coupled to a sound source, which is not shown in Figure 1.

For a person skilled in the art of technical acoustics, it is immediately evident that, inter alia, the characteristics of the sound-emitting surface 2, its shape, the size of its surface area, it thickness and, above all, also its mechanical characteristics together with the configuration of the oscillating coil or coils 3 and 4 as well as their local arrangement on the sound-emitting surface 2 govern the acoustic characteristics of the flat surface loudspeaker 1. Since, for example, completely different materials can be used for the sound-emitting surface 2, this itself results in a difficulty in material selection. This is because this depends on whether the flat surface loudspeaker 1 has a high level of attenuation, on the one hand in particular in the higher frequency range, as in the case of wooden materials, or on the other hand in the low-frequency range as, for example, in the case of glass and plastics so that, in the latter case, high frequency components are reproduced excessively, thus resulting in a tendency to tinkling.

These problems have resulted in flat surface loudspeakers not so far being used in large numbers in intrinsically feasible applications, even though the principles relating to this have been known for a very long time, since other electroacoustic transducers are known whose frequency response can be corrected more easily.

In order to solve this problem, Figure 1 now also shows a measurement arrangement by ~~means~~ way of which the transmission characteristics of a flat surface loudspeaker 1 are analyzed acoustically. In order to determine the frequency response of the measurement object, that is to say of a specific type of flat surface loudspeaker 1, a frequency analyzer 6 is provided which emits a defined electrical measurement signal to the amplifier 5 at a predetermined level and at a tunable frequency, and causes the flat surface loudspeaker 1 to emit sound via the oscillating coils 3, 4. A measurement microphone 7, which is connected to the input of the frequency analyzer 6, is arranged at a defined distance from the flat surface loudspeaker 1, preferably along its center axis.

The frequency response of the measurement object is determined using this measurement arrangement, which is preferably set up in an anechoic room, in order to simulate sound propagation in free space as exactly as possible in measurement conditions. As indicated above, this frequency response of a flat surface loudspeaker 1 is governed by object-typical nonlinearities, for which reason it must be measured individually, at least for each object type. This results in an essential measure for the electroacoustic transmission characteristics of a flat surface loudspeaker 1. The inverse function of the frequency curve obtained in this way is formed in order to compensate for the nonlinearities of the frequency response.

Figure 2 uses an operating circuit for the flat surface loudspeaker 1 to illustrate, schematically, how the described measurement result is used in order to correct for the distortion in the transmission

characteristics of a specific electroacoustic transducer. By way of example, the sound source is illustrated in Figure 2 in the form of a magnetic tape recorder 7, whose output is connected to the amplifier 5 for the flat surface loudspeaker 1, via a filter device 8. As is indicated schematically in Figure 2, a transfer function is implemented in the filter device 8 which is essentially the inverse of the characteristic frequency curve

measured for this type of flat surface loudspeaker 1. The profile of the transfer function of the filter device 8 must be approximated more closely to the inverse frequency curve of the flat surface loudspeaker 1 the more stringent the requirements to which the resultant transmission quality of the flat surface loudspeaker 1 is subject in the respective application.

In the filter device 8, the electrical sound signals supplied from the magnetic tape recorder 8 are subjected to preemphasis in such a way that this just counteracts the frequency response of the flat surface loudspeaker 1. This sound signal, with preemphasis, is supplied via the amplifier 5 to the oscillating coils 3, 4 of the flat surface loudspeaker 1. The transfer function of the conversion to acoustic signals in the flat surface loudspeaker 1 counteracts this preemphasis once again. The resultant frequency response of the flat surface loudspeaker 1 is better linearized the more accurately the transfer function of the filter device 8 approximates to the inverse frequency curve of the flat surface loudspeaker 1.

As is known, electrical filters can also be formed from discrete elements, but complex transfer functions for a bandpass filter in the audible range, such as those which are used in this field of application in conjunction with flat surface loudspeakers 1, can be provided using discrete components only with great complexity, and then only to a first approximation. Implementations of the filter device 8 using discrete components are therefore suitable in conjunction with a flat surface loudspeaker 1 only when its transmission quality is subject only to restricted requirements in a particular application.

¶ Figure 3 thus shows a further embodiment for the operating circuit of a flat surface loudspeaker 1, by ~~means~~ way of which even hifi (high fidelity) requirements can be satisfied. The embodiment shown in Figure 3 differs from the embodiment shown in Figure 2 in the further refinement of the filter device 8. Figure 3 shows the filter device 8 as a digital filter. Its

input circuit, which is connected to the magnetic tape recorder 7 (which is indicated once again as an example of a sound source) is in the form of a sample and hold element 9 - frequently also referred to as a sample and hold circuit. The electrical sound signal supplied as an analogue signal from the magnetic tape recorder 8 is thus sampled using a predetermined sampling theorem, and the respectively sampled instantaneous value is buffer-stored and is supplied to an analogue/digital converter 10 which is connected to it and which converts the successive instantaneous values to digital signals expressed in binary form. The signals are supplied in this form to a digital signal processor 11. On the output side, the digital signal processor 11 is connected to a digital/analogue converter 12, by means of which its binary output signal is converted back to an analogue electrical signal, which is supplied via the amplifier 5 to the flat surface loudspeaker 1.

This refinement of the filter device 8 advantageously makes use of the progress in the development of digital signal processing. Nowadays, the semiconductor industry offers the user powerful signal processors, which are already in widespread use, even for real-time applications. Application options for digital signal processors as well as refinements by means of appropriate programs can therefore be assumed to be known in this case. The circuit design of the digital signal processor is therefore not shown in detail in the schematic illustration in Figure 3. Normally, in addition to a microcontroller, the actual control unit, has a signal processor a program memory, a data memory and an input/output memory, which are connected to one another via a bus system with parallel address, control and data lines. The capability to store a

specific program relating to the respective application in the program memory makes the digital signal processor suitable for an electronic circuit which can be used universally and, in the present field of application, is used to simulate the transfer function of the filter device 8.

It is advantageous in this case for the filter or filters to be in the form of FIR (Finite Impulse Response) filters, by ~~means of~~ which even complex transfer functions for real-time requirements can be provided in a known manner. If the transmission quality of the flat surface loudspeaker is subject to very stringent requirements, such as those for hifi quality, in a specific application, then, owing to the signal processing required in real-time conditions, it may be necessary to carry out this signal processing by parallel operation of a number of signal processors, without in the process needing to depart from the fundamental solution approach.

The embodiments described above open up a wide range of applications for flat surface loudspeakers. The capability to program the digital signal processor 11 freely allows the complexity for the measurement of the frequency response of the respective type of flat surface loudspeaker 1 and the conversion of the measured frequency curve to an inverse transfer function (which is a greater or lesser approximation of this) of the filter device 8 to be optimized for the respective application. Both physically small and large format flat surface loudspeakers can be produced. Since the choice of materials for a flat surface loudspeaker designed according to the invention is no longer to a major extent subject to the conventional restriction, even materials with a very low relative density, for example, can also be chosen for the sound-emitting surface. Particularly in mobile applications, in which transport capabilities invariably play a substantial role, it is a major advantage to move a light flat surface loudspeaker composed of polyurethane foam instead of a heavy, voluminous conventional loud

speaker box. Flat surface loudspeakers according to the invention can thus be used not only for commercial purposes, such as public sound-emission facilities and advertising hoardings, but also as high-quality loudspeaker device in the personal field, which are at the same time very flat and, for example, are integrated in furniture.

VARIATIONS
CH

What is claimed is:

~~Patent Claims~~

(Amended)

1. A method for operation of a flat surface loudspeaker (1), in which at least one oscillating coil (3, 4) is mounted on a surface (2) in the form of a plate and having predetermined material characteristics, comprising: via which ¶ emitting sound is emitted by a at least one coil or coils (3, 4) stimulated to oscillate electrically by means of a sound source (7), stimulated to oscillate, characterized in that ¶ measuring the acoustic frequently frequency response of this flat surface loudspeaker is measured and ¶ determining a its frequency curve; is determined, in that the ¶ determining an inverse frequency curve to this the frequency curve is determined, in that this; ¶ simulating the inverse frequency curve is simulated in a filter device (8) as its a transfer function of the filter device (7); and in that ¶ compensating for the frequency response of the flat surface loudspeaker is compensated for by means of the filter device (8), which is connected between the sound source (7) and the flat surface loudspeaker (1) in the an operating state, on the basis of its based upon the transfer function.

(Amended)

2. The method as claimed in claim 1, characterized in that wherein the transfer function of the filter device (8) is simulated by digital filters.

(Amended)

3. The method as claimed in claim 2, characterized in that wherein the transfer function is formed by means of FIR (Finite Impulse Response) filters, whose filter coefficients are derived from the inverse frequency curve.

(Amended)

4. A flat surface loudspeaker comprising: ¶ having at least one oscillating coil (3, 4) which is, mounted on a surface (2) in the form of a plate and has defined

material characteristics and which, when stimulated by electrical sound signals, causes this surface (2) to oscillate in order to emit sound, characterized in that, and a filter device (8) for the sound signals, is connected upstream of the at least one oscillating coil (3, 4), and its , whereby a transfer function of the filter device is the inverse of the a frequency response of the flat surface loudspeaker (1).

5. (Amended) The flat surface loudspeaker as claimed in claim 4, [characterized in that] wherein the filter device [(8)] is in the form of a digital filter.

6. (Amended) The flat surface loudspeaker as claimed in claim 5, [characterized in that] wherein the filter device [(8)] is formed by FIR (Finite Impulse Response) filters.

7. (Amended) The flat surface loudspeaker as claimed in [one of claims] claim 5 [or 6], [characterized in that] wherein the filter device [(8)] [has a] includes a sample and hold element [(9)] as the input element, [which is] connected via an analogue[/]-to-digital converter [(10)] to the digital filter [(for example 11)], whose output is connected to a digital[/]-to-analogue converter [(12)].

8. The flat surface loudspeaker as claimed [in one of claims] claim 5 [to 7], [characterized in that] wherein the filter device [(8)] is equipped with a digital signal processor [(11)].

New claims

9. Same as 7, but dep on 6

10. Same as 8, but dep on 6

11. Same as 8, but dep on 7

12. Same as 8, but dep on 9

13. The method of claim 1, wherein the at least one oscillating coil is mounted on a surface in the form of a plate.

14. The method of claim 1, wherein the at least one oscillating coil has predetermined material characteristics.

15. The flat surface loudspeaker as claimed in claim 4, wherein the at least one oscillating coil is mounted on a surface in the form of a plate.

16. The flat surface loudspeaker as claimed in claim 4, wherein the at least one oscillating coil has predetermined material characteristics.

GR 99 P 1665 MARKED-UP VERSION OF ABSTRACT

Abstract

~~Flat~~ surface ~~loudspeaker, and a method for~~ its ~~operation~~

~~A~~ In a method for operation of a flat surface loudspeaker ~~(1) is disclosed~~, in ~~which~~ at least one oscillating coil ~~(3, 4)~~ is mounted on a surface ~~(2)~~ in the form of a plate and ~~having~~ includes predetermined material characteristics. ~~which~~ The surface ~~(2)~~ is caused to oscillate by the at least one oscillating coil, which is stimulated electrically by a sound source ~~(7)~~. The acoustic frequency response of this flat surface loudspeaker is measured, and the inverse frequency curve to this frequency curve is determined. This inverse frequency curve is simulated in a filter device ~~(8)~~ as its transfer function. ~~In the operating arrangement, this filter device is connected between the sound source (7) and the flat surface loudspeaker (1), so that the frequency response of the flat surface loudspeaker is compensated for by its transfer function. This frequency response compensation for the flat surface loudspeaker makes it possible to improve its transmission characteristics such that even hifi requirements can be satisfied.~~

~~Significant figure: Figure 2~~

Description

Flat surface loudspeaker, and a method for its operation

The invention relates to a flat surface loudspeaker as claimed in the precharacterizing clause of patent claim 4, and to a method for its operation as claimed in the precharacterizing clause of patent claim 1.

Flat surface loudspeakers of said generic type have been known per se for a long time, for example from German Patent 484 872. An oscillating coil is used in a flat surface loudspeaker, operating on the electrodynamic principle and being placed directly on a surface - intrinsically initially of any desired size and thickness and composed of a chosen material -, and being mechanically fixed there. When the oscillating coil is stimulated electrically by a sound transmitter, then its oscillations are transmitted to the surface, which acts as a membrane, so that it is itself used as a sound-emitting surface. There will be a large number of potential applications per se for an electroacoustic transducer of this generic type. Apart from a few exceptions, it has nevertheless not been used to any major extent so far owing to its electroacoustic characteristics, in particular its transfer function.

The operation of the sound-emitting surface is primarily governed by its mechanical characteristics. This surface can transmit sounds or tones only by oscillating mechanically. Quite apart from the means by which it is clamped in, that is to say the mechanical mounting and the point at which the oscillating coil is fixed on it, a surface in the form of a plate in which,

preferably, bending oscillations are stimulated is intrinsically a relatively complex structure in terms of its oscillation behavior. Whereas with commercially available loudspeakers based on the electrodynamic principle it is still largely possible, even if actually only by making compromises, to optimize the acoustic characteristics

of the sound-emitting membrane, this is not directly possible with flat surface loudspeakers. This problem can be illustrated by an example: if the glass surface of a shop window on which an oscillating coil is mounted is used as a flat surface loudspeaker, then the material, shape and dimensions of the sound-emitting surface, and the way in which it is clamped in as well, are essentially fixed. In this example, the frequency response of the flat surface loudspeaker is thus essentially predetermined. Typically, the natural resonances of the surface used for sound emission and with this material and the dimensions of the shop window have a frequency response which - in simple terms - can be described by enhanced response in the low frequency area and, furthermore, by a tendency to produce a tinkling noise, which is due to the influence of higher-order natural resonances that are still in the audible range. Corresponding characteristic nonlinearities also occur with other materials, such as wood or synthetic materials.

A flat surface loudspeaker having a built-in sound wall is known from GB 2 265 519 A, which has nonlinearities in transmission owing to the internal air pressure and the magnetic field in the transducer. The nonlinearities are taken into account by means of digital electronic compensation; the loudspeaker contains power amplification. This allows the loudspeaker to be designed to be much thinner than would otherwise be possible. The drive forces are exerted on a major proportion of a membrane in order to avoid modal distortion which occurs in the sound-emitting surface at low and medium frequencies. The loudspeaker is suitable for wall mounting, with minimal projection into the room.

GB 289 185 A discloses an acoustic reproduction appliance, for amplification of the power on an audiosignal, which has been modified by means of a nonrecursive digital filter, and which emits the sound via a loudspeaker. The reproduction appliance has a sound funnel in the form of a horn on the loudspeaker, as well as means for signal processing of the audio signal, comprising a nonrecursive digital filter. An acoustic resistance can be mounted on the opening of the loudspeaker horn. The filter has an inverse characteristic to the transmission characteristic of the loudspeaker horn, including the acoustic resistance. Furthermore, the reproduction appliance may have a linear phase equalizer for modulation of the amplitude characteristic of the audio signal. The digital filter in the signal processing means may be in the form of a digital FIR (Finite Impulse Response) filter.

EP 0 168 078 A1 discloses an arrangement for converting an electrical signal to an acoustic signal or vice versa, which has an electroacoustic transducer and means for reducing the distortion in the output signal from the arrangement. The means are in the form of a nonlinear network which has at least two parallel circuit branches, at least one of which compensates for the second or higher order nonlinear distortion components.

An appliance to compensate for reproduction errors in an electroacoustic transducer, such as a loudspeaker or a microphone, by means of a computer circuit is known from US 4,675,835. The electrical input signals are converted in a digital computer circuit to output signals which have been modified by inherent characteristics

of the transducer, and are stored in a memory by means of a program. The program is stored in the same way. When analogue computer circuits are used, the complex inherent reproduction of the transducer, in terms of the amplitude/frequency transmission and the phase/ frequency transmission, is approximated mathematically in a closed inverse form, and the resulting function is simulated by means of integrated, addition, inversion and adjustment elements.

A method and a system for transmission of audio frequencies in a sound reproduction system are disclosed in EP 0 567 061 A1, which sound reproduction system has at least one loudspeaker mounted in a housing, and in which the frequency transmission of the loudspeaker is equalized by means of a filter. Before feeding in a signal in a broadband one-way loudspeaker, which reproduces frequencies essentially over the entire audible range, with said loudspeaker emitting audio signals, the frequency transmission of the loudspeaker when mounted in its housing is equalized by means of a filter, which is likewise a broadband filter covering the entire audible range. The filter provides an approximated inverse transmission in the desired pass band of the loudspeaker system, which comprises said loudspeaker mounted in its housing, with the inverse transmission being formed on the basis of the measured frequency transmission of the loudspeaker system. If desired, the measured frequency transmission can be averaged in the frequency domain, and the inverse transmission is then formed from the averaged frequency transmission.

As is known, for example, from US-A-3 728 497 as well as US-A-3 636 281 or US-A-3 449 531, efforts have been made to overcome the known disadvantages of a flat surface loudspeaker by means of physical measures. Certain improvements have been possible in this way, but a fundamental solution which would give flat surface loudspeakers a wide range of applications has not yet been obtained from the experiments carried out so far.

The invention is thus based on a first partial object of specifying a means, using a method of the type mentioned initially, using which the nonlinearities in the frequency response of flat surface loudspeakers can at least be coped with to such an extent that their sound spectrum is sufficiently natural for the respective application.

A second partial object is to use such a method to provide a flat surface loudspeaker of the type

mentioned initially, whose electroacoustic characteristics are - depending on the application - optimized such that predetermined requirements in an individual application relating to the quality of sound produced in this way are thus satisfied.

In a method of this generic type for operating a flat surface loudspeaker, the first partial object is achieved by the features described in the characterizing part of patent claim 1.

In a flat surface loudspeaker of the type mentioned initially, the second partial object is achieved by the features described in the characterizing part of patent claim 4.

In the field of electroacoustics, it has long been known in the development of optimized electroacoustic transducers that the effects of the influencing variables which govern the transmission quality of an electroacoustic transducer often counter one another in a contrary manner. A physical/mechanical solution in which all these influencing variables are optimized in the same way is thus impossible, and every electroacoustic transducer is invariably a compromise solution, due to systematic factors. One relevant example of this is the known loudspeaker box, with a number of individual, specifically designed loudspeakers. The solutions to the two partial objects according to the invention are based on the joint idea that such compromises, which are characterized by physical measures, have far less probability of leading to a satisfactory result in a flat surface loudspeaker. A flat surface loudspeaker is actually not composed of individual, specifically designed loud speaker units,

like a loudspeaker box. The development of flat surface loudspeakers so far has shown that solution approaches which attempted to improve flat surface loudspeakers by physical measures did not lead to a satisfactory result.

The invention is a departure from the conventional ideas of electro-acousticians and adopts a different approach. The electroacoustic characteristics of flat surface loudspeakers are governed by the total effect of the characteristics of the oscillating coil or coils used, and by the mechanical characteristics of the sound-emitting surface that is used. The electroacoustic transfer function for each arrangement of a flat surface loudspeaker defined in this way is thus defined in the form of its frequency response - apart from tolerances. If the corresponding frequency curve is determined by measurement, then the frequency response of the flat surface loudspeaker can be compensated for, and hence linearized, by means of a filter device which is arranged in the operating arrangement of the flat surface loudspeaker between the sound source and the amplifier located upstream of the oscillating coil or oscillating coils, provided the transfer function of the filter device is essentially the inverse of the corresponding function for the combination of an oscillating coil or coils and the sound-emitting surface.

According to developments of the invention, the transfer function of the filter device is simulated by means of digital filters, in particular by means of FIR (Finite Impulse Response) filters, whose filter coefficients are derived from the inverse frequency curve of the flat surface loudspeaker.

The filter device preferably has a sample and hold element as the input element, which is connected via an analogue/digital converter to the digital filter, whose output is connected to a digital/analogue converter.

According to another development of the invention, the filter device is equipped with a digital signal processor.

Nowadays, digital signal processors are widely used and, owing to the progress in the development of integrated circuits, are also already available for relatively

computation-intensive "real time" applications. Digital signal processors are freely programmable, even if this is only to a limited extent due to the available volume for the program memory. It is thus possible to match the operation of the digital signal processor to different sound-emitting surface materials, such as wooden materials, glass, plastics, and, inter alia, polyurethane foam. Furthermore, it is also possible to provide sound-emitting surfaces with different shapes. It is thus clear that the invention has, in particular, overcome the greatest obstruction to the widespread use of flat surface loudspeakers in the past. The shape and material selection for the sound-emitting surface are largely unconstrained, without any need to accept any reduction in the sound emission quality. Although very high quality, which is thus still relatively expensive due to complexity reasons, is not required for every application, it is nevertheless feasible to implement embodiments which even completely satisfy hifi (high fidelity) requirements. Volume and weight savings with flat surface loudspeakers compared to commercially available loudspeaker boxes are a major advantage, and not only in these applications.

Further advantages and refinements of the solution according to the invention can be found in the following description of exemplary embodiments.

Exemplary embodiments of the invention will be described in more detail in the following text with reference to the drawing, in which:

Figure 1 shows a flat surface loudspeaker in conjunction with a measurement arrangement for measuring its frequency response,

Figure 2 shows a first embodiment of the circuit arrangement for operating the flat surface loudspeaker, and

Figure 3 shows a further embodiment of the circuit arrangement as shown in Figure 2.

Figure 1 shows, schematically, a flat surface loudspeaker 1 which has a sound-emitting surface 2 in the form of a plate and on which, by way of example, two oscillating coils 3 and 4 are arranged. The oscillating coils 3 and 4 are mechanically fixed on the sound-emitting surface 2 such that, when they are electrically stimulated, the mechanical oscillations which they carry out in this case are transmitted to the sound-emitting surface 2 in order that it is itself caused to oscillate, and hence to emit sound. In a functional operating circuit, the oscillating coils 3, 4 are connected in parallel to the outputs of an amplifier 5 whose input, during normal operation, is coupled to a sound source, which is not shown in Figure 1.

For a person skilled in the art of technical acoustics, it is immediately evident that, inter alia, the characteristics of the sound-emitting surface 2, its shape, the size of its surface area, it thickness and, above all, also its mechanical characteristics together with the configuration of the oscillating coil or coils 3 and 4 as well as their local arrangement on the sound-emitting surface 2 govern the acoustic characteristics of the flat surface loudspeaker 1. Since, for example, completely different materials can be used for the sound-emitting surface 2, this itself results in a difficulty in material selection. This is because this depends on whether the flat surface loudspeaker 1 has a high level of attenuation, on the one hand in particular in the higher frequency range, as in the case of wooden materials, or on the other hand in the low-frequency range as, for example, in the case of glass and plastics so that, in the latter case, high frequency components are reproduced excessively, thus resulting in a tendency to tinkling.

These problems have resulted in flat surface loudspeakers not so far being used in large numbers in intrinsically feasible applications, even though the principles relating to this have been known for a very long time, since other electroacoustic transducers are known whose frequency response can be corrected more easily.

In order to solve this problem, Figure 1 now also shows a measurement arrangement by means of which the transmission characteristics of a flat surface loudspeaker 1 are analyzed acoustically. In order to determine the frequency response of the measurement object, that is to say of a specific type of flat surface loudspeaker 1, a frequency analyzer 6 is provided which emits a defined electrical measurement signal to the amplifier 5 at a predetermined level and at a tunable frequency, and causes the flat surface loudspeaker 1 to emit sound via the oscillating coils 3, 4. A measurement microphone 7, which is connected to the input of the frequency analyzer 6, is arranged at a defined distance from the flat surface loudspeaker 1, preferably along its center axis.

The frequency response of the measurement object is determined using this measurement arrangement, which is preferably set up in an anechoic room, in order to simulate sound propagation in free space as exactly as possible in measurement conditions. As indicated above, this frequency response of a flat surface loudspeaker 1 is governed by object-typical nonlinearities, for which reason it must be measured individually, at least for each object type. This results in an essential measure for the electroacoustic transmission characteristics of a flat surface loudspeaker 1. The inverse function of the frequency curve obtained in this way is formed in order to compensate for the nonlinearities of the frequency response.

Figure 2 uses an operating circuit for the flat surface loudspeaker 1 to illustrate, schematically, how the described measurement result is used in order to correct for the distortion in the transmission

characteristics of a specific electroacoustic transducer. By way of example, the sound source is illustrated in Figure 2 in the form of a magnetic tape recorder 7, whose output is connected to the amplifier 5 for the flat surface loudspeaker 1, via a filter device 8. As is indicated schematically in Figure 2, a transfer function is implemented in the filter device 8 which is essentially the inverse of the characteristic frequency curve

measured for this type of flat surface loudspeaker 1. The profile of the transfer function of the filter device 8 must be approximated more closely to the inverse frequency curve of the flat surface loudspeaker 1 the more stringent the requirements to which the resultant transmission quality of the flat surface loudspeaker 1 is subject in the respective application. In the filter device 8, the electrical sound signals supplied from the magnetic tape recorder 8 are subjected to preemphasis in such a way that this just counteracts the frequency response of the flat surface loudspeaker 1. This sound signal, with preemphasis, is supplied via the amplifier 5 to the oscillating coils 3, 4 of the flat surface loudspeaker 1. The transfer function of the conversion to acoustic signals in the flat surface loudspeaker 1 counteracts this preemphasis once again. The resultant frequency response of the flat surface loudspeaker 1 is better linearized the more accurately the transfer function of the filter device 8 approximates to the inverse frequency curve of the flat surface loudspeaker 1.

As is known, electrical filters can also be formed from discrete elements, but complex transfer functions for a bandpass filter in the audible range, such as those which are used in this field of application in conjunction with flat surface loudspeakers 1, can be provided using discrete components only with great complexity, and then only to a first approximation. Implementations of the filter device 8 using discrete components are therefore suitable in conjunction with a flat surface loudspeaker 1 only when its transmission quality is subject only to restricted requirements in a particular application.

Figure 3 thus shows a further embodiment for the operating circuit of a flat surface loudspeaker 1, by means of which even hifi (high fidelity) requirements can be satisfied. The embodiment shown in Figure 3 differs from the embodiment shown in Figure 2 in the further refinement of the filter device 8. Figure 3 shows the filter device 8 as a digital filter. Its

input circuit, which is connected to the magnetic tape recorder 7 (which is indicated once again as an example of a sound source) is in the form of a sample and hold element 9 - frequently also referred to as a sample and hold circuit. The electrical sound signal supplied as an analogue signal from the magnetic tape recorder 8 is thus sampled using a predetermined sampling theorem, and the respectively sampled instantaneous value is buffer-stored and is supplied to an analogue/digital converter 10 which is connected to it and which converts the successive instantaneous values to digital signals expressed in binary form. The signals are supplied in this form to a digital signal processor 11. On the output side, the digital signal processor 11 is connected to a digital/analogue converter 12, by means of which its binary output signal is converted back to an analogue electrical signal, which is supplied via the amplifier 5 to the flat surface loudspeaker 1.

This refinement of the filter device 8 advantageously makes use of the progress in the development of digital signal processing. Nowadays, the semiconductor industry offers the user powerful signal processors, which are already in widespread use, even for real-time applications. Application options for digital signal processors as well as refinements by means of appropriate programs can therefore be assumed to be known in this case. The circuit design of the digital signal processor is therefore not shown in detail in the schematic illustration in Figure 3. Normally, in addition to a microcontroller, the actual control unit, has a signal processor a program memory, a data memory and an input/output memory, which are connected to one another via a bus system with parallel address, control and data lines. The capability to store a

specific program relating to the respective application in the program memory makes the digital signal processor suitable for an electronic circuit which can be used universally and, in the present field of application, is used to simulate the transfer function of the filter device 8.

It is advantageous in this case for the filter or filters to be in the form of FIR (Finite Impulse Response) filters, by means of which even complex transfer functions for real-time requirements can be provided in a known manner. If the transmission quality of the flat surface loudspeaker is subject to very stringent requirements, such as those for hifi quality, in a specific application, then, owing to the signal processing required in real-time conditions, it may be necessary to carry out this signal processing by parallel operation of a number of signal processors, without in the process needing to depart from the fundamental solution approach.

The embodiments described above open up a wide range of applications for flat surface loudspeakers. The capability to program the digital signal processor 11 freely allows the complexity for the measurement of the frequency response of the respective type of flat surface loudspeaker 1 and the conversion of the measured frequency curve to an inverse transfer function (which is a greater or lesser approximation of this) of the filter device 8 to be optimized for the respective application. Both physically small and large format flat surface loudspeakers can be produced. Since the choice of materials for a flat surface loudspeaker designed according to the invention is no longer to a major extent subject to the conventional restriction, even materials with a very low relative density, for example, can also be chosen for the sound-emitting surface. Particularly in mobile applications, in which transport capabilities invariably play a substantial role, it is a major advantage to move a light flat surface loudspeaker composed of polyurethane foam instead of a heavy, voluminous conventional loud

speaker box. Flat surface loudspeakers according to the invention can thus be used not only for commercial purposes, such as public sound-emission facilities and advertising hoardings, but also as high-quality loudspeaker device in the personal field, which are at the same time very flat and, for example, are integrated in furniture.

Patent Claims

1. A method for operation of a flat surface loudspeaker (1), in which at least one oscillating coil (3, 4) is mounted on a surface (2) in the form of a plate and having predetermined material characteristics, via which sound is emitted by a coil or coils (3, 4) stimulated electrically by means of a sound source (7), stimulated to oscillate, characterized in that the acoustic frequently response of this flat surface loudspeaker is measured and its frequency curve is determined, in that the inverse frequency curve to this frequency curve is determined, in that this inverse frequency curve is simulated in a filter device (8) as its transfer function, and in that the frequency response of the flat surface loudspeaker is compensated for by means of the filter device (8), which is connected between the sound source (7) and the flat surface loudspeaker (1) in the operating state, on the basis of its transfer function.

2. The method as claimed in claim 1, characterized in that the transfer function of the filter device (8) is simulated by digital filters.

3. The method as claimed in claim 2, characterized in that the transfer function is formed by means of FIR (Finite Impulse Response) filters, whose filter coefficients are derived from the inverse frequency curve.

4. A flat surface loudspeaker having at least one oscillating coil (3, 4) which is mounted on a surface (2) in the form of a plate and has defined

material characteristics and which, stimulated by electrical sound signals, causes this surface (2) to oscillate in order to emit sound, characterized in that a filter device (8) for the sound signals is connected upstream of the at least one oscillating coil (3, 4), and its transfer function is the inverse of the frequency response of the flat surface loudspeaker (1).

5. The flat surface loudspeaker as claimed in claim 4, characterized in that the filter device (8) is in the form of a digital filter.

6. The flat surface loudspeaker as claimed in claim 5, characterized in that the filter device (8) is formed by FIR (Finite Impulse Response) filters.

7. The flat surface loudspeaker as claimed in one of claims 5 or 6, characterized in that the filter device (8) has a sample and hold element (9) as the input element, which is connected via an analogue/digital converter (10) to the digital filter (for example 11), whose output is connected to a digital/analogue converter (12).

8. The flat surface loudspeaker as claimed in one of claims 5 to 7, characterized in that the filter device (8) is equipped with a digital signal processor (11).

Abstract

Flat surface loudspeaker, and a method for its operation

A method for operation of a flat surface loudspeaker (1) is disclosed, in which at least one oscillating coil (3, 4) is mounted on a surface (2) in the form of a plate and having predetermined material characteristics, which surface (2) is caused to oscillate by the at least one oscillating coil, which is stimulated electrically by a sound source (7). The acoustic frequency response of this flat surface loudspeaker is measured, and the inverse frequency curve to this frequency curve is determined. This inverse frequency curve is simulated in a filter device (8) as its transfer function. In the operating arrangement, this filter device is connected between the sound source (7) and the flat surface loudspeaker (1), so that the frequency response of the flat surface loudspeaker is compensated for by its transfer function. This frequency response compensation for the flat surface loudspeaker makes it possible to improve its transmission characteristics such that even hifi requirements can be satisfied.

Significant figure: Figure 2

FIG 1

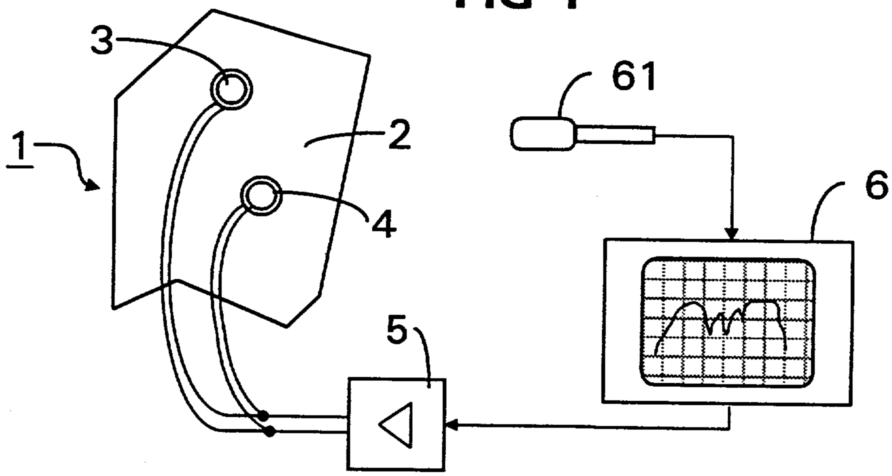


FIG 2

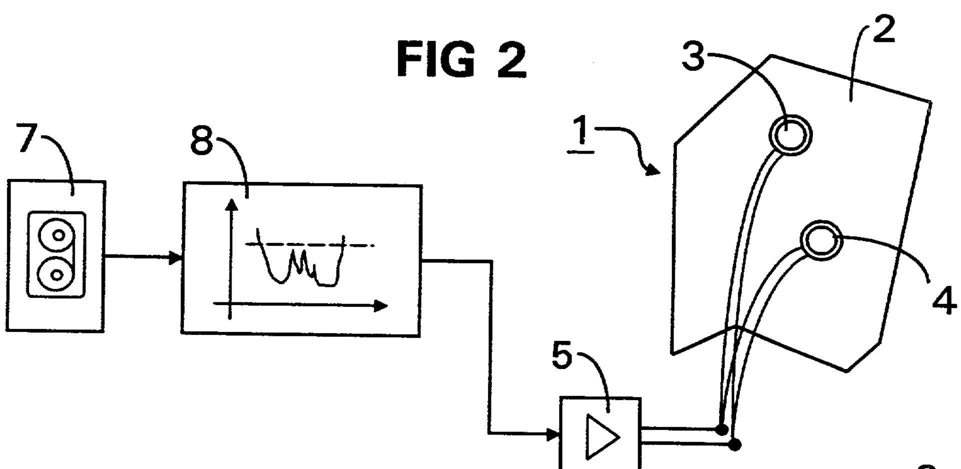
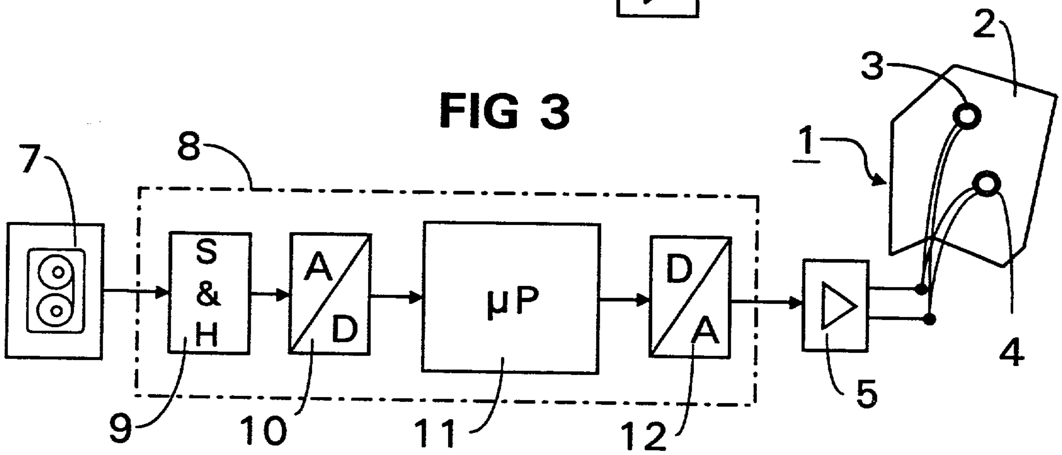


FIG 3



PATENT
32860-000181

IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicants: Robert BOESNECKER

Int'l Application No.: PCT/DE99/03377

Application No.: **NEW**

Filed: October 19, 2001

For: FLAT SURFACE LOUDSPEAKER, AND A METHOD FOR ITS OPERATION

CHANGE OF ADDRESS AND REVOCATION AND SUBSTITUTION OF POWER OF ATTORNEY

Hon. Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

Under 37 C.F.R. § 3.73(b), the undersigned hereby states that the below-named Assignee is an assignee in the above-identified Application:

Assignee: **SIEMENS AKTIENGESELLSCHAFT**

The documentary evidence of a chain of title from the original owner to the Assignee is provided in the Assignment Document(s):

☒ filed herewith,

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I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements, and the like so made, are punishable by fine or imprisonment, or both, under Section 1001, Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

As a below named inventor, I hereby declare that:

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

My residence, post office address and citizenship are as stated below next to my name,

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I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Flächenlautsprecher und Verfahren zu dessen Betrieb

Flat surface loudspeaker and method for operating the same

deren Beschreibung

(zutreffendes ankreuzen)
☐ hier beigefügt ist.
☒ am 21.10.1999 als
PCT internationale Anmeldung
PCT Anmeldungsnummer PCT/DE99/03377
eingereicht wurde und am ________
abgeändert wurde (falls tatsächlich abgeändert).

the specification of which

(check one)
☐ is attached hereto.
☒ was filed on 21.10.1999 as
PCT international application
PCT Application No. PCT/DE99/03377
and was amended on ________
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Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

German Language Declaration

Prior foreign appplications
Priorität beansprucht

Priority Claimed

19917584.5	DE	19.04.1999	☒	☐
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	Yes Ja	No Nein
			☐	☐
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	Yes Ja	No Nein
			☐	☐
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	Yes Ja	No Nein

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/DE99/03377	21.10.1999		pending
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D, M, Y) (Anmeldedatum T, M, J)	(Status) (patentiert, anhängig, aufgegeben)	(Status) (patented, pending, abandoned)
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D,M,Y) (Anmeldedatum T, M; J)	(Status) (patentiert, anhängig, aufgeben)	(Status) (patented, pending, abandoned)

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

New U.S. Application
Docket No. 32860-000181

POWER OF ATTORNEY

The Declaration submitted along with this application includes a Power of Attorney listing the attorneys of Birch, Stewart, Kolasch & Birch, LLP. Please hereby revoke the aforementioned attorneys and substitute the attorneys of Customer No. 30596, including the following attorneys of Harness, Dickey & Pierce, P.L.C., to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Terry L. Clark	Registration No. 32,644
Donald J. Daley	Registration No. 34,313
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Gary D. Yacura	Registration No. 35,416
Thomas S. Auchterlonie	Registration No. 37,275
Timothy R. Wyckoff	Registration No. 46,175

CORRESPONDENCE ADDRESS

I request the Patent and Trademark Office to direct all correspondence and telephone calls relative to this application to Customer No. 30596, Harness, Dickey & Pierce, P.L.C., P.O. Box 8910, Reston, Virginia 20195, (703) 390-3030.

The undersigned is empowered with full Power of Attorney on behalf of the assignee.

Respectfully submitted,

HARNESS, DICKEY & PIERCE, P.L.C

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DJD:kna

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